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CENTRAL INTELLIGENCE AGENCY

INFORMATION REPORT

[redacted]

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COUNTRY : USSR

SUBJECT : Research and Development Activities of the Junkers Kuibyshev Group

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DATE OF INFORMATION [redacted] 25X1

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NO. OF ENCLS. 9 (LISTED BELOW)

SUPPLEMENT TO REPORT NO.

THIS IS UNEVALUATED INFORMATION

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[redacted]

1. The JUMO 012 (Project A)

25X1 (a) [redacted] concerning the compressor details. In 1947 two versions existed. One had a constant outer diameter, the other had an outer diameter which increased from front to rear. Later, the former was built.

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25X1 (b) [redacted]

Compressor: 10 stages. Compression ratio: 4 - 4.5 : 1
Air Mass Flow: 60 kg/sec

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Turbine : Two versions - one stage and two stages ([redacted]

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Exhaust Bullet	:	Two positions (starting and maximum thrust)
Starter	:	Compressed air turbine installed / diffuser cone
Thrust	:	Static test - about 3,000 kg attained

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25X1 (c) [redacted] the 012 was in series production, but [redacted] only that all necessary drawings had been completed and turned over to the Soviets. Stoppage of work on this project was explained to us as due to a more efficient power plant having been developed elsewhere by the Soviets. No state test run was ever made on the 012.

2. Project C

(a) Project C was a further development of the JUMO 022 turboprop engine. Extensive effort on it commenced in 1950. The Soviets specified that it was to have an equivalent horsepower rating of six thousand (German horsepower - PS) with a specific fuel consumption of 280 grams of fuel per horsepower per hour. The following specifications were set up for the components:

(1) Compression ratio : 7 : 1
(2) Air Mass flow : 29 kilograms per second
(3) Compressor efficiency: 89%
(4) Combustion efficiency: 98%
(5) Turbine efficiency : 90%

(b) A preliminary performance study determined that the following would be required:

(1) Propeller : 5.20 meters diameter. 930 RPM.

(2) Compressor: 14 stage, axial flow. Tip speed of rotors about 280 meters per second. 9000 RPM. First stage hub-tip ratio of 0.6.

(3) Turbine : Two possibilities considered - two or three stage turbine.

(c) The compressor design was to be such that the Mach number of the airstream velocity over the outer section of each rotor blade was to be equal to the Mach number over the inner section of the following stator blade for the first three stages. In calculations, an elliptical circulation over the chord was assumed for all blade sections.

(d) The compressor housing was to be an aluminum casting with the stator and guide vanes fixed in the housing. For the first test vehicle it was planned to have the stator blades manually adjustable through a small range of angles of attack. The calculations for the compressor were completed in September 1950, with the first blade and stage designs being completed also. [redacted]

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3. The JUMO 022 (Project B)

(a) General Design

(1) The JUMO 022 turboprop engine was developed by the Germans at Kuibyshev from the design stage through a 200-hour qualification run [redacted] in September 1950. Sketch 1, Enclosure (A) is a schematic layout of the 022 with some of the thermodynamic data.

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(2) Combustion temperature was 750° centigrade. [redacted] a turbine inlet temperature of 1100° Kelvin was later allowed. (Korb was formerly a Junkers test stand engineer at Dessau. He returned from the USSR in July 1951, and now works at the Turbinenfabrik, Dresden.) Fuel consumption was 310 to 320 grams per horsepower per hour. [redacted] this was improved in 1951 to 300 grams per horsepower per hour by improving the compressor efficiency. What this improvement entailed was not known [redacted] Engine RPM was 7700, prop RPM was 1028. Power of most models was about five thousand SHP. [redacted] A maximum air inlet velocity of 200 meters per second was assumed in performance calculations.

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(3) With propeller installed (tractor) the unit measured about 5.8 meters long. Without propeller it was approximately four meters long. Maximum diameter of the engine (without propeller) was 1053 mm (not including external accessories). Total weight was 1500 kg divided as follows:

Compressor - 500 kg
Combustion chamber, turbine and exhaust - about 500 kg
Reduction gearing and inlet housing - about 300 kg
Accessories - about 200 kg

The inlet housing was of dural. All other non-rotating parts (compressor housing, tail pipe, etc) were of steel.

(b) Compressor

(1) General

a. The first design had 14 rotor and 15 stator stages, an air mass flow of 30 kg/sec and a compression ratio of 5:1. It closely resembled the JUMO 004 compressor, having scaled up dimensions. The additional stages were similar to the last stage of the 004 compressor. This compressor was designed in Dessau, and, as far as I know, the 022 was a postwar development. The scaling up of the blade airfoils was done after the war. This was done by Eberl; (he worked for DVL during World War II). In 1948 the stage graphs of the JUMO 004 were still being used in decisions on the 022 concerning blade setting angles for single compressor stages.

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25X1 b. Very little of a practical nature was known about compressors [redacted] in 1948. The compressor could only be tested on the complete engine, thus limiting measurements to the points at which the entire unit could be run. Except for starting and stopping, the engine was to be run at a constant RPM, with variations in power being accomplished by variations in the amount of fuel burned.

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The airflow varied only about three percent from idle to full power at constant RPM. In order to obtain additional data, some tests were run with constant load and variable RPM and others with variable load and constant RPM, all with the waterbrake. In some of these tests, short periods of higher than normal temperatures into the turbine were permitted.

c. Air mass flow was measured prior to the first guide vane in the inlet. Static pressure was measured by stage and at the rear of the compressor. Normally, only temperatures entering and leaving the compressor were read. In some tests, though, free stream thermocouples were employed to take readings after every other stage. Later mantled thermocouples were used to read total temperatures.

d. The few available measurements indicated that efficiency of the compressor was very low. The maximum airflow measured was 31.2 kg/sec with a compression ratio of 4.5, and an adiabatic efficiency of 0.78. Stage loads varied considerably. Cold days produced even poorer results with higher RPM.

e. The engineers knew that some of the measurements were inaccurate. Experiments were made with different blade twists. Several compressors were built but not all had completely new bladings. The most difficulty was experienced with the final stage. Some changes were made in the stator stages, also, in order to remove vibration faults and other defects occurring in fabrication.

f. By the end of 1948, the work had progressed sufficiently far that a new compressor had been designed having a compressor ratio of 6:1. This compressor had straight-in flow to the first turbine stage permitted by removing the inlet guide vanes. This was done to reduce the relative Mach number of the airflow over the first blades. The inlet was redesigned to increase the diffuser recovery factors. This resulted in an increase in the outer diameter of the first rotor stage to 635 mm. The succeeding stator stage reduced this to 618 mm, which was the outer diameter of all following stages.

g. As the single stage test stand had not been built, it was decided that a whole compressor built with this new arrangement was too risky a proposition. Therefore, the first two stages were redesigned for straight-in flow to the first stage, using an outer diameter of 618 mm for all stages. In tests of this, such favorable results were obtained that it was accepted as the configuration to be used. An adiabatic efficiency of .82 and a compression ratio of 5:1 were obtained. The performance at higher RPM also improved. It was with this layout that the first State Test Run was made.

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h. The third compressor configuration had the enlarged first stage, redesigned second stage, and with the following stages unchanged. Listed below are the types of compressors used on the 13 engines which were built:

1 through 7 :	618 mm outer diameter with inlet guide vanes
8 through 10 :	618 mm outer diameter with no inlet guide vanes
11 through 13:	635 mm diameter for first stage, all others 618 mm, with no inlet guide vanes

i. Shortly after the testing of the new first stage, an additional change on the compressor resulted in more favorable performance. The clearance between the rotor blades and the compressor casing was about 1.5 to 2 mm before starting. The interference at the blade tips apparently had little influence on the first stages. In later stages, and particularly the last several, however, the disruption of the airflow caused by clearance was quite important. In order to dimish these effects, the rings (compressor wall) were lined with a mixture of enamel and talcum powder. See Sketch 2, Enclosure (A). Centrifugal forces caused some radial lengthening of the blades when running the engine so it had to be accelerated slowly when starting. The blades scraped the lining and made their own paths in them. This improved the performance of the compressor somewhat as at full power, clearance between blade tips and the wall was practically zero. Some trouble was experienced at first, in that the enamel-talcum coating cracked during operations. This was eliminated by varying the percentages of constituents until a satisfactory coating was obtained.

j. The final step in this development was the running of the engine in the Soviet State Test Run. The compressor as used had an adiabatic efficiency of 0.85, an air mass flow of 31.2 kg/sec, and a 5.3:1 compression ratio. This was engine Number 11. On this compressor the pitch ratio at the tip of the first rotor stage was 1.25, at the second stage, it was 1.26, and at the third, 1.22. All three stages had the same airfoil section. The second and third stages had the same blade twist, differing only in angle of attack and the fairing of the blade into the foot. The remainder of the compressor (no change essentially from previous compressors) had pitch ratios varying between 1.1 and 1.25 at the rotor tips.

k. The airfoil sections for the first three stages were of the NACA 000d/1 - 64 series (taken from an American report). The tip section thickness ratios were 5%, the root thickness ratios were 9%, with a linear increase along the blade from tip to root. The following rotor stages had airfoils taken from the Goettingen Airfoil Catalogue and had thickness ratios of about 25%. Pitch ratios of the stator stages were between 0.8 and 0.9, except for the last stage, which had a pitch ratio of about 1.4.

(2) Pressure Relief

a. Preliminary calculations indicated that the turbine could perform useful work (i e, drive the compressor) only at RPM above five thousand. Therefore, a starter was needed which could drive the engine to that speed. The inability of the turbine to do the work was because of a large pressure surge in the middle stages. An increase in the amount of fuel being burned would have taken care of this, but would have resulted in too high initial turbine temperatures. In order to relieve this pressure surge, blow-off valves were installed at the fifth and sixth stator stages. The valves were spring loaded and hydraulically controlled. They were designed to remove about 25% of the air flow, thus reducing the pressure at the first, sixth and seventh rotor stages to just over the optimum at 3,000 RPM. In starting, the engine was driven with the valves open to about three thousand RPM, fuel ignited; at about 4200 RPM the starter was disconnected, and at 5500 RPM the valves were closed. All test engines had this pressure relief.

b. Unfavorable effects would be obtained if the engine had to be stopped or throttled down very much in flight. This would necessitate reopening the valves when restarting or accelerating and would introduce the problem of what to do with the airflow coming from the relief valves. Some thought was given to systems whereby the air would be reintroduced to the first rotor stage, or controllable pitch blades on the first stage would eliminate the need for the relief valves. A third solution involved, essentially, a variable cross sectional area. A "rubber compressor" could not be built, but an attempt at simulating this was made by constructing ahead of the first rotor stage, a wall, which for starting, produced a satisfactory pressure distribution. This was made as shown in Sketch 3, Enclosure (A), with the height of the wall being 35 mm. The pressure relief valves were not needed with this arrangement. It was purely experimental, though, and no attempts were made to develop a retractable arrangement or some other similar solution which would eliminate the effects of the wall after starting had been accomplished.

25X1 c. [redacted] an episode [redacted] occurred in connection
25X1 with the test of this set-up. There was some opinion in the minds of various engineers, including the Soviets, that this system would not work and also that it might damage the compressor. Kusnizoff, the Chief Technical Designer, was present at the test, which was conducted by Deinhardt. [redacted] drilled two rows of holes in the wall in order to improve the airflow characteristics over it. In starting, the air going through these holes produced a loud noise. Kusnizoff and his Soviet assistants made a hurried exit from the test stand. The test went off smoothly, however, but Kusnizoff stated later that if anything should happen during one of the tests, it would be much better if he was not present at the time.

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(3) Construction of the Compressor

a. The housing of the compressor separated at the center line (in the horizontal plane). The rotor discs in earlier versions were bolted together as shown at Point 1, Enclosure (B) and all were solid from the shaft out. Later versions had the central portion of every other disc eliminated, Point 2, Enclosure (B). Rotor blades had dovetailed feet as shown at Point 1, Sketch 1, Enclosure (C). The sides of the feet, Point 2, Sketch 1, Enclosure (C), were inclined at 15 degrees. The blades were so designed that under normal operating conditions the bending moments caused by the airflow were compensated to some degree by the centrifugal forces imposed by rotation. This was, of course, true at only one operating condition. The number of blades in each stator stage was a prime number. This was based on common machine tool manufacturing practices. The first and third stator stages had 31 blades, but I do not know the quantities in the other stages. The blades in the first eight stages of the compressor were made of aluminum while the last six stages had steel blading. The rings, Sketch 2, Enclosure (C), and Sketch 2, Enclosure (A) for the blades were rolled from 1.5 mm thick sheet steel. These were finished only on their outer surfaces, but, as mentioned previously, they were lined later with an enamel-talcum powder coating.

b. During the entire period [redacted] 25X1 [redacted] no rotor blades failed owing to the effects of vibrations. Much trouble was encountered with the stators, though. Many breaks occurred both in blades and in mountings. The early stator stages had rolled and milled inner and outer rings. In these the head and feet of the blades were welded into stamped holes. Breaks appeared primarily at the holes, in the trailing edges of the blades, and about a third of the way from each end of the blades. See Sketch 3, Enclosure (C). Thickness ratio and pitch ratio were varied, and different materials were used in attempts to eradicate these faults. As soon as one stage had been remedied, another stage would develop troubles. The most satisfactory method and that which was finally adopted, had the rings stamped out as shown in Sketch 4, Enclosure (C) and reinforced with sheet metal strips as shown at Point 1, of the same sketch. The blades were welded alternately (peripherally) to the inner and outer rings, while the unwelded ends had a small amount of clearance and could move somewhat under stress. Three of the blades in each stage in each half of the compressor section were welded at both ends, in order to tie the inner and outer rings together.

(4) Compressor Performance

25X1 a. A detailed questionnaire was used in obtaining the following information. [redacted] however, could supply no information to many of the questions. This is indicative of the comparatively primitive equipment at Zavod #2 and the lack of necessary reference matter. As a result,

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important factors in compressor design had to be left uninvestigated. This meant that the 022 engine was not a completely scientific enterprise.

b. The outer diameters of the rotor stages of the 022 compressors were constant (618 mm) with the exception of the one compressor whose first stage had an outer diameter of 635 mm. With an engine speed of 7700 RPM, the blade tip speed of each stage can be determined. Enclosure (D) is a table giving values for hub-tip ratios, blade areas, polytropic efficiency, enthalp change, temperature increase, total temperature and pressure rise for each of the 14 stages. [redacted] calculated this table during the process of the interrogation and believed it to be quite correct.7 The calculated values shown on the table had not been checked in tests [redacted] did not consider three-dimensional flow problems as being important and so did not investigate them.

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c. [redacted] do not know the blade thicknesses for all stages. The relative angles of attack for the first stage in all compressors were zero degrees, the second and third ran from .5 to one degree, and the fourth through fourteenth varied from two to eight degrees (rotor only).

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d. The intake diffusor recovery factory was about .89. [redacted] no measures were developed to improve operations under abnormal conditions. Calculations were performed using a constant engine RPM and independent of the altitude and airspeed.

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e. [redacted] nothing concerning surging and stalling of the compressor at critical speeds, stress data, and combustion chamber and turbine work other than that reported elsewhere in this report.

f. In the 022, axial flow components were assumed constant. Deviations from this owing to wall interference were not measured. Their existence was acknowledged, however, and attempts made to reduce them by adjusting blade setting angles. When designing the compressor for Project C, calculations of three-dimensional flow were made for each stage. [redacted]

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g. Reports of research performed at TSIAM indicated that radial equilibrium was attained immediately after each rotor and stator stage. These reports were the result of experimental tests on British theoretical results.

h. In order to obtain high efficiency at low densities, the flow entering each stage had axial velocities such that the resultant exit velocity was as low as possible. Those sections of a blade which had the highest velocity (rotor blade outer section and stator blade inner section) had short chords with thickness ratios of about 40%.

i. Some experimental work was done on higher stage loads. A single stage was tested in September 1950, but I do not know the results. In the Development

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Department, research into a compression ratio of 6.0 in nine stages was done. Some calculations were also performed on a two-sectioned, 10 stage compressor.

j. In a general discussion on compressors in the winter of 1948-49, Oleschnowitsch spoke in opposition to increasing stage loads. He stated that three years before, many people had advocated fewer stages with higher compression ratios per stage. Other research centers in the USSR had worked on them and failed (poor starting and altitude performances). The same people who had previously been for fewer stages were now advocating more and more stages. He advised them that they should work slowly and carefully in order to prevent future failures.

k. The problem of heat exchangers came up and was worked on, but dropped because of excessive weight and large pressure drops.

l. No after-burning was considered because of the high fuel consumption and attendant weight. In a number of tests it was found that the temperature between the first and second stages of the 022 turbine was higher than that before the first stage. It was decided that this was the result of incomplete combustion prior to the first stage, with burning continuing going into the second stage.

m. No research was done at Zavod #2 on the use of jet engine air intakes for boundary layer control.

n. Facilities for high performance research were essentially non-existent at Zavod #2. [redacted] the aircraft group at Podberezye also had no high speed wind tunnel. Two small high velocity tunnels at Dessau, Germany, were rebuilt after World War II. One was sent to the USSR prior to October 1946 and the other afterwards -- both to unknown destinations. The pressurized engine test cell taken from Dessau to Zavod #2 remained in its packing cases throughout my stay. Groebner, who had been responsible for this cell at Dessau, was ordered to inspect the crates to determine whether the cell was complete. [redacted]

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(c) Turbine

(1) The turbine section did not utilize the same theory for developing the 022 turbine as had been used for the compressor. Dr Schroeder [redacted] discussed the fact that apparently it was based on steam turbine theory without any correction. [redacted] this was influenced by Kuemmel (Thermodynamics Department) who was of the "old school". [redacted] could not understand why Dr Cordes continued to utilize this "primitive theory". Dr Schroeder, however, did not believe that it was wise [redacted] to interfere with the turbine people in this matter because the cooperation between the two groups had been very good and he did not want working relationships to suffer.

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(2) [redacted] The turbine stages were designed using sub-critical velocities. [redacted] two or three stages were used on the last model built, but [redacted] for test discussions, the use of three stages was always paramount. The Turbine Department always furnished turbine guide vane setting angles of 21, 23, and 25 degrees (from front to rear) to the compressor people for use in their calculations. Much experimenting was done with the turbine in attempts to obtain the desired efficiency, but without much theoretical work being performed.

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(3) The turbine blades (rotor) had fir tree roots (See Sketch 1, Enclosure (E)), and were lightly riveted at the base to prevent axial movement. The fit of the root into the disc was loose; insertion or removal of a cold blade could easily be done by hand.

(4) Some vibration breaks occurred on turbine blades. Dr Schmidt told me that too few of these had been found for them to determine the exact cause. A turbine test stand had been planned for thorough investigation of the turbine, but was not built because of lack of necessary funds.

(5) Assembly of the turbine shaft to the compressor shaft was rather difficult. This had to be done from the turbine end of the combustion chamber. For this reason access holes were cut in the combustion chamber forward wall and inner cone. Sketches 2 and 3, Enclosure (E), show this with relation to the compressor and combustion chamber and details of the joint.

(d) Combustion Chamber

(1) I saw the combustion chamber only on the complete engine and had some contact with the personnel doing this work in some of the conferences. I was able to see some of the design drawings at these conferences but my recollections of this were hazy.

(2) The combustion chamber assembly included the rear compressor and the front turbine supports. The housing for this section was in one piece, not separated for removal as was that for the compressor. For a cross section of the combustion chamber, see Sketch 1, Enclosure (F).

(3) The big problem in the combustion chamber design was to eliminate the hot spots in the airflow to the turbine inlet. In 1950 this was still not satisfactorily solved. The temperature distribution was unequal both radially and circumferentially, with measured readings showing up to 200 degrees Celsius difference between points. The accuracy of these readings was questioned but they did show that there were great inequalities present. The highest temperatures seemed to appear at the top of the engine, which fact Brandner blamed on the difference in density between differently heated gas particles. [redacted]

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a. This was made by a Soviet plant in Moscow [redacted] 25X1 [redacted] German specialists at 25X1 Zavod #2 were consulted in the design and construction. The propeller section consisted of the two contra-rotating propellers, shaft, pitch control and reduction gearing. The diameter of the propeller was 4.5 meters and the two planes were about 800 mm apart. Each consisted of four blades. Maximum RPM was 1028. The forward prop rotated in a clockwise direction when looking from the engine. Prop output was in the ratio of 1.3 (front) to 1 (rear).

b. Pitch control was hydraulic and the propellers were full-feathering, reversible, constant speed.

c. The blades were solid forged aluminum, with all blades being made from the same die. Strains imposed on the hub-blade transition during forging sometimes caused ruptures at this point during tests.

d. In addition to this propeller, other designs for the 022 were studied under the leadership of Engineers Lorenzen and Bockermann. These were, among others, synchronized twin-propellers, double-hood propellers, and an eight (8) bladed prop. None of these went any further than the design stages.

ILLEGIB (2) [redacted]

a. The goal in the design of the contra-rotating propellers was, of course, greatest power absorption and efficiency for smallest weight and size. The preliminary design was an attempt to load all gears equally. This arrangment had the disadvantages of unequal blade loading and a large diameter casing (585 mm). This was almost the same as the compressor rotor diameter thereby affecting unfavorably the air inlet characteristics. See Sketch 1, Enclosure (H).

b. To reduce the diameter, research was made into the scheme shown in Sketch 2, Enclosure (H). This was a better system in some respects, but was dropped in favor of the first scheme because of the first's more advantageous power ratio (on the gear train).

c. A power take-off for the starter and other accessories was located as shown at Point 1, Enclosure (G).

d. Oil was fed from the gear casing along the shaft to the pitch control through rings and slots (Point 2, Enclosure (G).

e. The transmission was a primary limiting factor in the performance of the 022. The optimum fuel consumption figures were obtained at measured horsepowers above six thousand (PS). The transmission, however, could not transmit this much power to the propellers. Various difficulties arose during tests, some of which were directly connected to the weaknesses of the reduction gearing.

f. On 20 Apr 49, one mishap occurred which the Soviets attempted to call an act of sabotage by the Germans, that date being Hitler's birthday. This was during the first State Test. The test was being run at night. From the control room the engine, but not the propellers could be seen. When the fault occurred an increase in noise level was detected but the engine continued to run normally. An external check, however, showed that the propellers had torn loose. Investigation revealed that a pinion had failed and jammed. This sheared the front gear casing bolts, thus allowing the propellers to come free. They were stopped from doing too much damage when they hit a post on a travelling crane. The maximum RPM of the compressor-turbine was limited to 7500 because of the reduction gearing limitations.

(f) Starter

(1) In early tests, using a water-brake for power absorption and measurement, the 022 was started by use of an electric motor. After the propeller was installed, the starting was accomplished by a compressed air turbine. In 1949, development of a gas turbine starter was begun. A special group was charged with this project having among its members, Engineer Weckwerth (formerly of BMW), who was the chief; Eberl (formerly with D.V.L.; returned to the Soviet Zone of Germany in 1950), and Stich. Eberl and Stich designed the compressor.

(2) I do not know much concerning the starter. I attended a conference once on its compressor airflow characteristics and heard that the starter was based on a British turbojet, supposedly being built under license in the USSR.

(3) The starter consisted of a centrifugal compressor (3 radial spirals), a combustion chamber, and an axial flow turbine. Electric power was used to turn over the starter initially. The JUMO 213 starter transmission supposedly was used. See Enclosure (I) for a sketch of the starter arrangement.

(4) The unit delivered 50 (PS) and weighed approximately 50 kg. A variation of this was started by the auxiliary air compressor on the compressor housing. I do not know which was finally used, nor do I know the air compressor's performance and characteristics.

(g) Accessory Section

(1) The accessory section included the generator, a two-cylinder reciprocating air compressor and storage tank for the starter and other accessories (flaps, gears, etc) which would operate by compressed air, fuel and oil pumps and filters, oil cooler, compressor

relief valves, tachometer, and engine controls. These were all attached to the compressor housing with the power transmission from the main shaft being located as shown at Point 1, Enclosure (G). This also was the means by which the starter drove the engine. I did not have much contact with the development of this equipment and, therefore, can not furnish detailed information.

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Enclosure (A) Schematic of 022
(B) 022 Compressor
(C) Rotor Blade Mounting
(D) Characteristics Chart
(E) Turbine Blade Details
(F) 022 Combustion Chamber Section
(G) 022 Reduction Gear
(H) 022 Reduction Gear
(I) 022 Gas Turbine Starter

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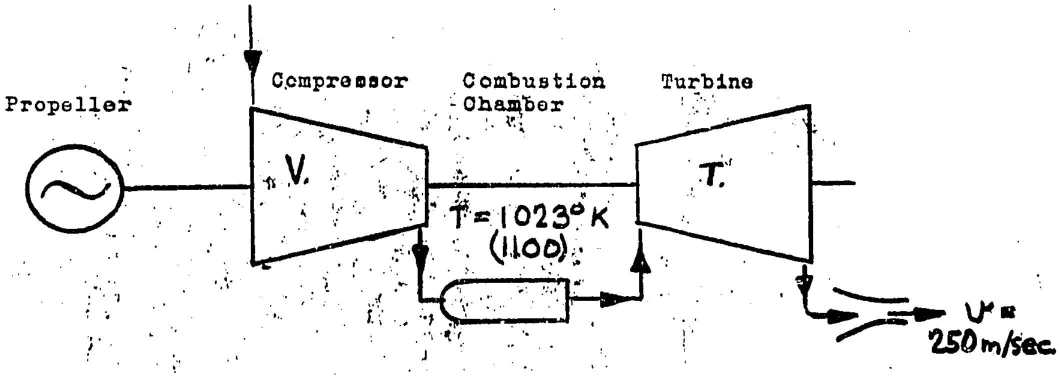
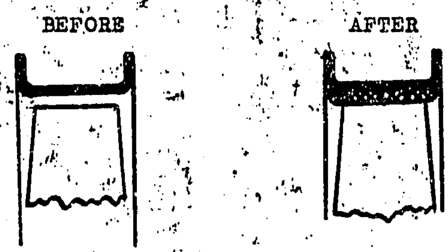
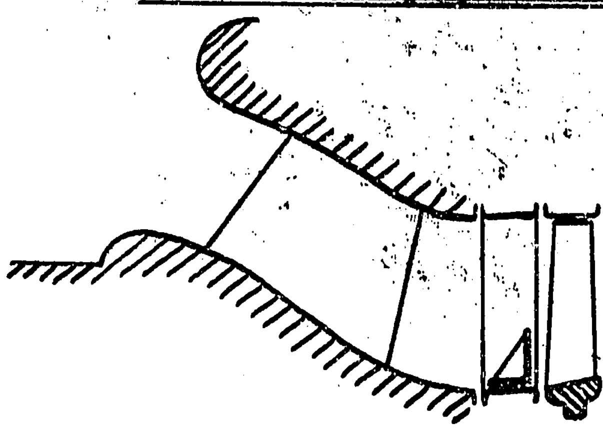
SKETCH NO. 1

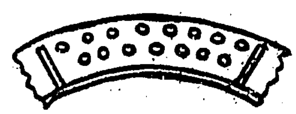




ENAMEL-TALCUM POWDER
LINING OF ROTOR RINGS

SKETCH NO. 2





EXPERIMENTAL STARTING
PRESSURE SURGE CONTROL

SKETCH NO. 3

ENCLOSURE (A)

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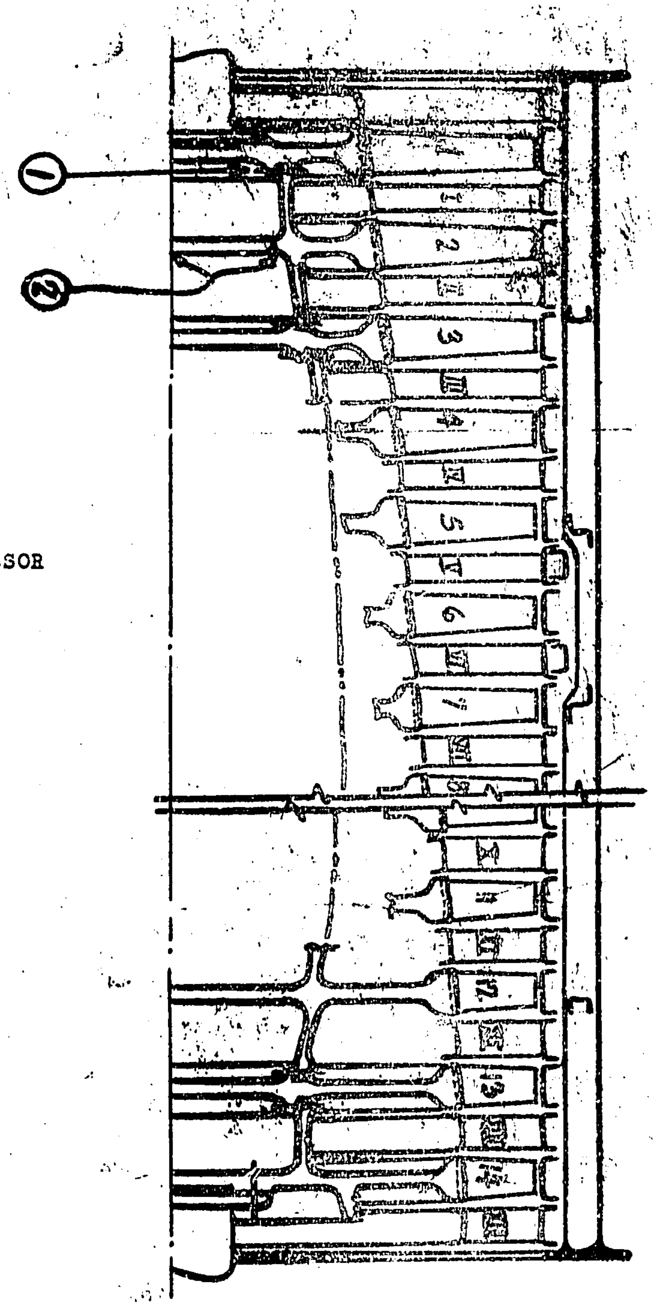

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ENCLOSURE (B)

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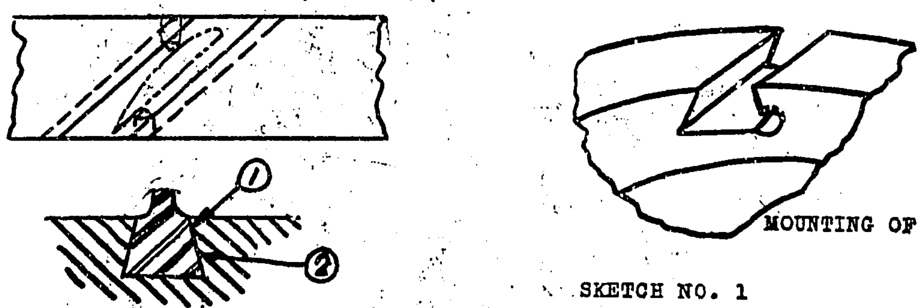
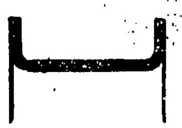
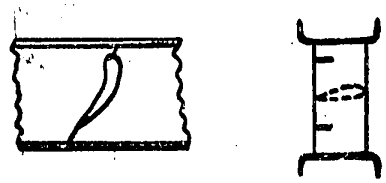


MOUNTING OF ROTOR BLADES

SKETCH NO. 1

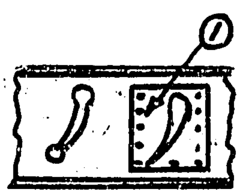


SKETCH NO. 2



STATOR BLADE CRACKING

SKETCH NO. 3



SKETCH NO. 4

SECRET

25X1

SECRET

25X1

022 . COMPRESSOR CHARACTERISTICS

Stage No	di/do	Area (m^2)	η(pol)	Δ H (pol)	Δ T (°C)	T (total)	Δ Pressure
1	0.540	0.2120	0.88	1500	16.4	288.0	1.189
2	0.561	0.2044	0.87	1430	16.0	304.4	1.169
3	0.580	0.1980	0.86	1340	15.2	320.4	1.150
4	0.598	0.1920	0.85	1300	14.9	335.6	1.139
5	0.620	0.1840	0.85	1350	15.5	350.5	1.138
6	0.638	0.1783	0.85	1420	16.3	366.0	1.138
7	0.660	0.1688	0.85	1470	16.8	382.3	1.138
8	0.685	0.1585	0.86	1450	16.4	399.1	1.129
9	0.712	0.1480	0.86	1400	15.9	415.5	1.120
10	0.735	0.1375	0.86	1340	15.2	431.4	1.110
11	0.748	0.1322	0.85	1299	14.8	446.4	1.102
12	0.760	0.1260	0.84	1250	14.5	461.4	1.095
13	0.776	0.1198	0.83	1200	14.1	475.9	1.088
14	0.798	0.1088	0.83	1150	13.5	490.0	1.083

Following Stage 14: 503.5

Total Compression Ratio: = 5.356

Adiabatic Temperature Increase: = 177.5°C

η (adiabatic) = 0.825

ENCLOSURE (D)

SECRET

SECRET

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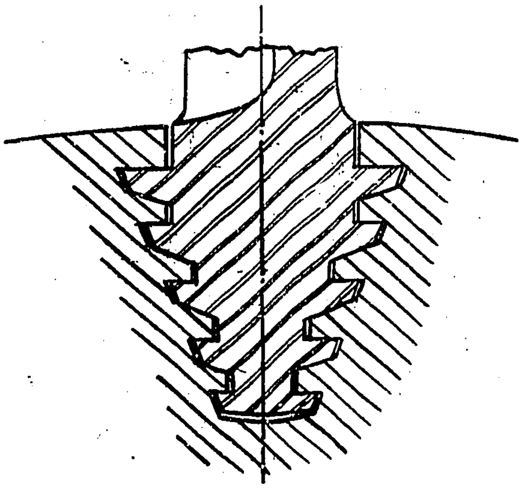
SECRET

SECRET

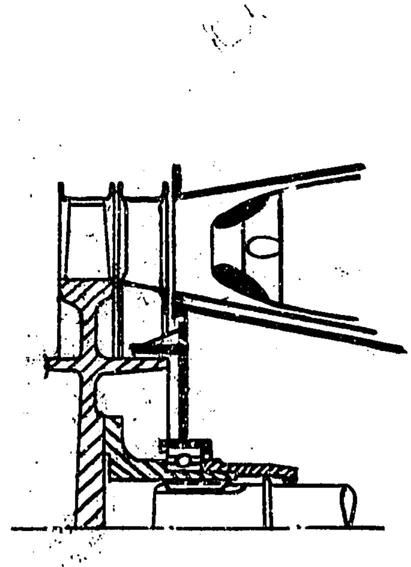
25X1

25X1



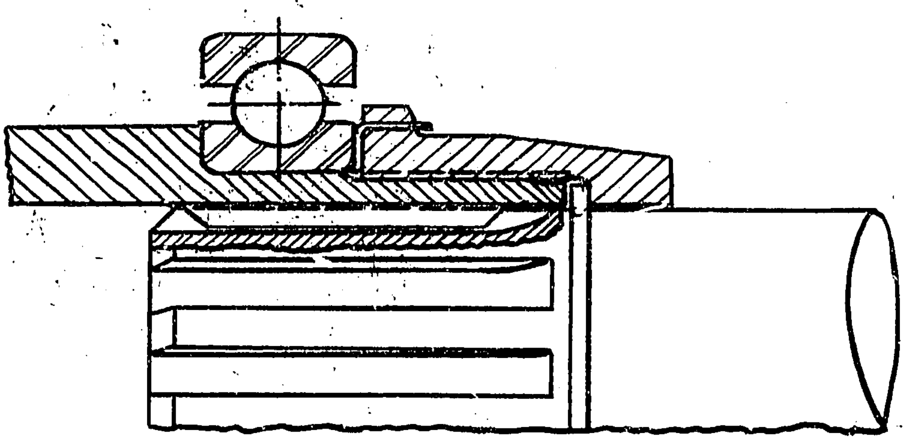
TURBINE BLADE ROOT

SKETCH NO. 1



COMPRESSOR-COMBUSTION CHAMBER
AND SHAFT JOINT

SKETCH NO. 2



SHAFT JOINT

SKETCH NO. 3

SECRET

25X1

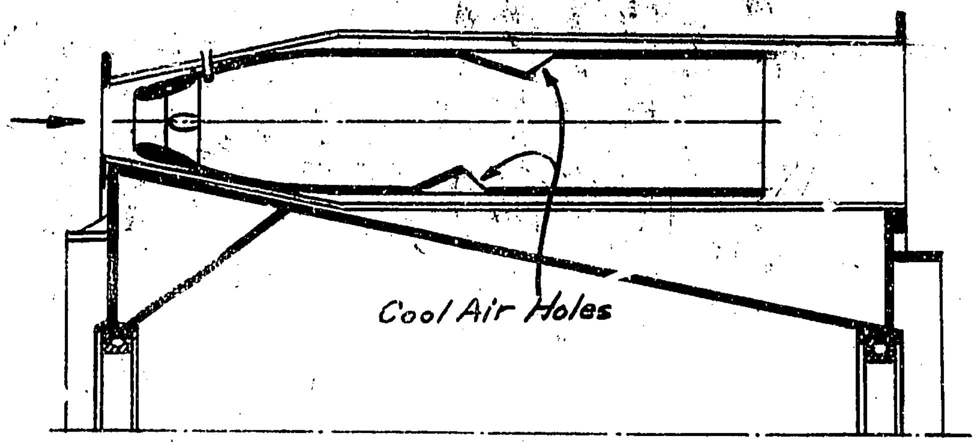
ENCLOSURE (E)

SECRET

SECRET

SECRET

25X1 25X1



022 COMBUSTION HAMBER SECTION

SKETCH NO. 1

SECRET

25X1

ENCLOSURE (F)

SECRET

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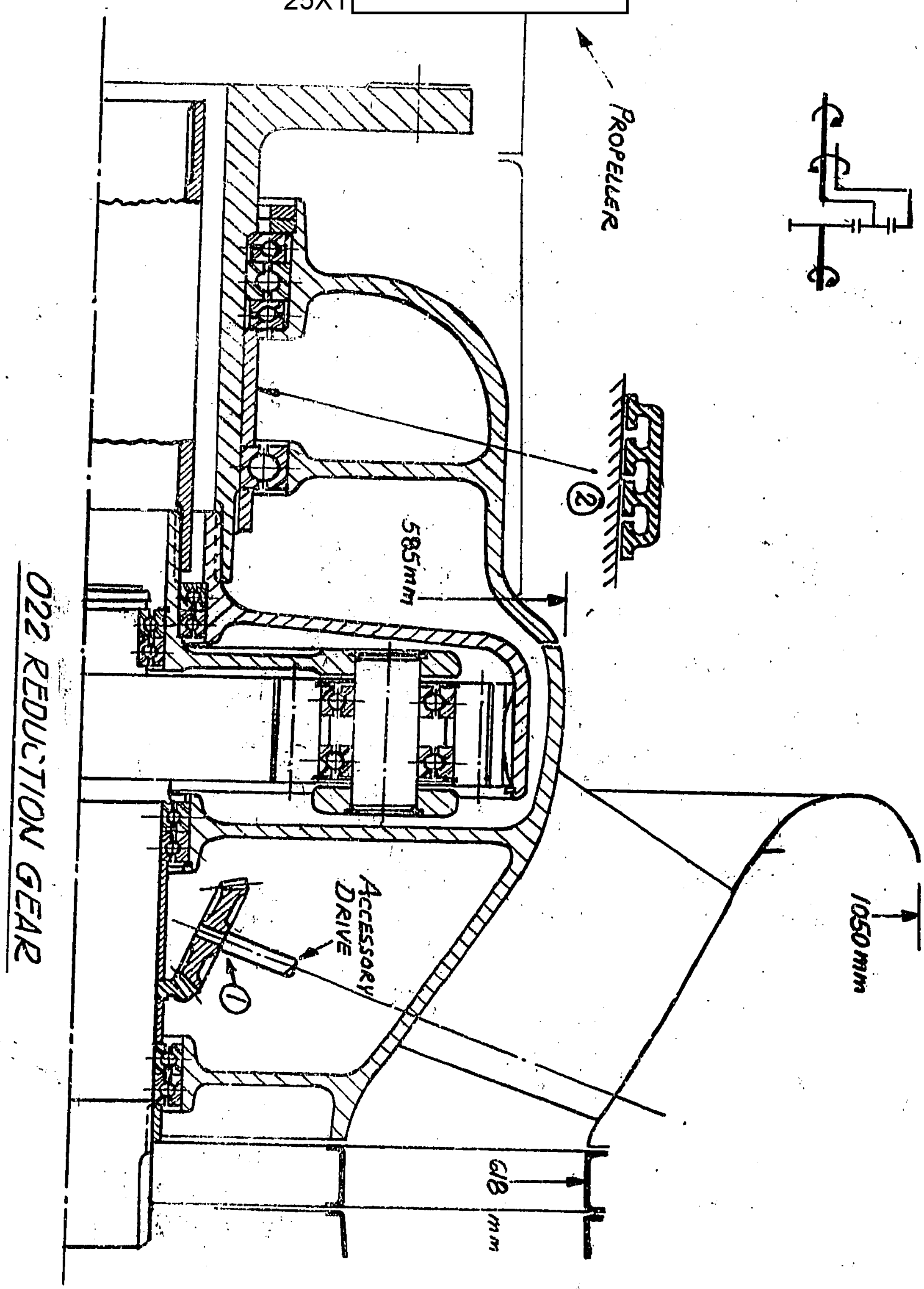
SECRET SECRET

25X1 25X1



SECRET

25X1

ENCLOSURE (G)

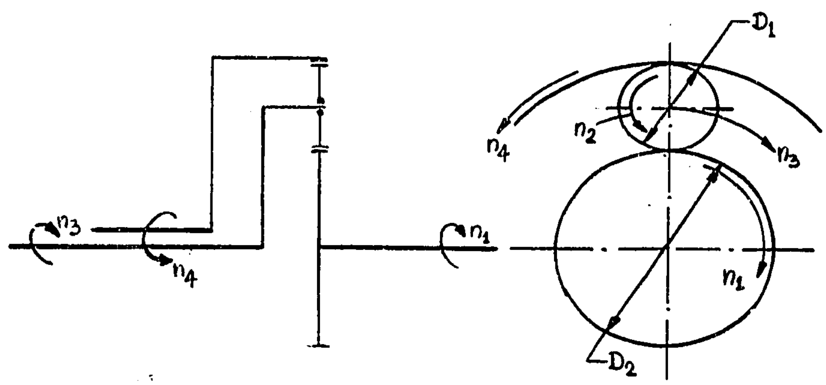
SECRET

SECRET

SECRET

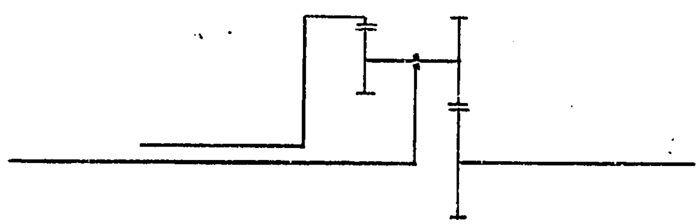
25X1

25X1



SKETCH NO. 1

022 REDUCTION GEARING



SKETCH NO. 2

PROPOSED 022 REDUCTION GEARING

SECRET

25X1

ENCLOSURE (H)

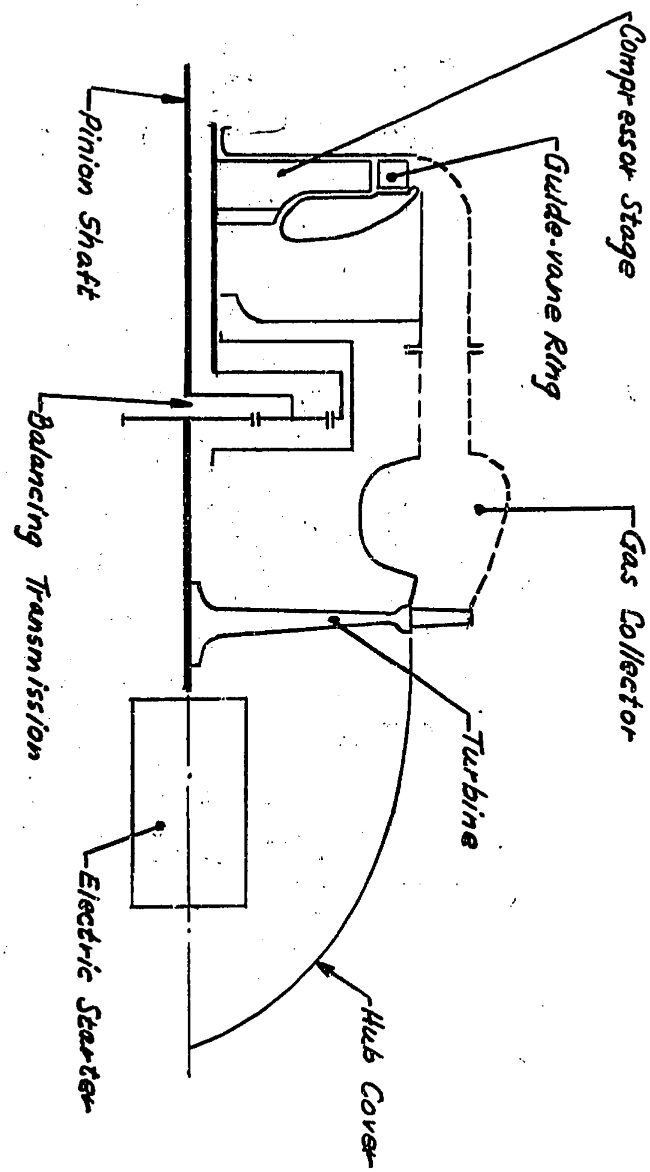
SECRET

SECRET

25X1

SECRET

25X1



022 GAS TURBINE STARTER

SECRET

25X1

ENCLOSURE (I)

SECRET